

one volume of which was exhibited, and the other promised in August next.

The meeting was then adjourned.

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*The Geology of the Diamantiferous Region of the Province of Paraná, Brazil. By Orville A. Derby, M. S. (English Version.)*

*(Read by permission of the Director of the Brazilian Museum before the American Philosophical Society, May 16, 1879.)*

A portion of the ancient Capitania of São Paulo, now the province of Paraná, has long been known to be diamantiferous, but as no extensive washings have ever been undertaken, and as the gems thus far found have been of small size, although of good quality and color, only very little attention has been attracted to this region, in comparison with the more fully explored diamond fields of the provinces of Minas Geraes and Bahia. During a recent excursion in Paraná, I was able to make some observations on the geology of the region in question, and on the mode of occurrence of the diamonds.

The province of Paraná lies between São Paulo on the north, and Santa Catharina and Rio Grande do Sul on the south, and extends from the Atlantic to the river Paraná, occupying about six degrees of longitude and three of latitude. Topographically it is divided into two very distinct regions: a mountainous region along the coast, extending about 100 miles inland, and a plateau region, occupying the central and western portions of the province. The first or mountainous region constitutes a distinct geological area, while the plateau portion is divided into two grand geological provinces. Strictly speaking, the whole province, with the exception of a coast belt from ten to twenty miles wide, is a plateau, the coast mountains, constituting a part of the great Serra do Mar system, but known in this province by the beautiful and appropriate name of the Serra Graciosa, rising abruptly from the coast belt, and forming the margin of a plateau. from 800 to 1000 metres in height. In the northeastern part of this great plateau, an interior range of mountains, a continuation of the Paraná-piacaba range of São Paulo, rises above the general level, but dies away towards the south. The coast belt, the Serra do Mar, and the eastern portion of the great interior plateau, whether mountainous, as in the north, or nearly level, as in the south, have the same general geological characters, and may properly be united together in what I will designate as the first or mountainous or, geologically speaking, the metamorphic region. The topography of this region, in the more mountainous portions, is bold and abrupt, with picturesque peaks, rising to a height of about 1500 metres above the sea, and 600 to 700 metres above the river valleys and the more level portions. The latter are, in general, moderately undulating prairies,

with strips and patches of forest. In the southern portion of the province one such area, of considerable size, extends from the Serra do Mar to the margin of the second region, and reaches northward to beyond the capital, Curityba. Another and much smaller area exists to the west of the second range of mountains, in the north of the province, about the city of Castro. This last is generally included in the second region, under the name of the Campos Geraes, but geologically it has nothing in common with those campos, and belongs to the first region.

The rocks of this region are all metamorphic, the beds being highly inclined, with a general strike E. N. E. Along the coast and in the Serra do Mar granite, porphyritic and schistose gneisses occur, as in the corresponding region of the province of Rio de Janeiro, with an abundance of igneous rocks, including diorite, porphyry and a compact variety with a basaltic structure. In the plains about Curityba epidotic rock occurs abundantly, with schistose gneiss; while farther west the latter is associated with metamorphic, noncrystalline, red schists, which are either talcose or hydromica, and with red, metamorphic porphyry, which is a more metamorphosed portion of the same schists. In the plains about and to the west of Curityba a thick deposit of decomposed material covers the rock and good exposures are rare. The rocks seen *in situ* are those above mentioned, but an abundance of pebbles of itacolomite and other varieties of quartzite attest the existence of other rocks in the vicinity.

Unfortunately I was unable to visit the northern mountainous portion of this region, about the head-waters of the river Ribeira, which is by far the most interesting part of the metamorphic belt. In the western margin of this district, which is known by the general name of Assunguy, I found the red schists and porphyries, above mentioned, extensively developed, with beds of white marble and iron ore. From the specimens and information I was able to obtain from this region, it appears to be very rich in marbles, iron ores and auriferous rocks. From about fifteen miles north of Curityba, I saw a greenish serpentine marble, identical with that associated with the same red schists near Sorocaba, province of São Paulo, and from other portions of the Assunguy region, I saw specimens of itacolomite and of the peculiar auriferous, ferruginous quartzite called Jacutinga, so characteristic of the metamorphic region of Minas Geraes. These specimens, and the few observations I was able to make, confirm the opinion I had already formed, that the non-crystalline metamorphic series, composed of quartzites (itacolomite, itabirite, jacutinga, etc.), talcose (hydromica?) schists and marbles,\* so characteristic of the interior of the provinces of Bahia and Minas Geraes, extend in a continuous belt to the southward, probably as far as Rio Grande do Sul, presenting everywhere the same essential characters.

I have elsewhere† presented reasons for referring the crystalline meta-

\*The crystalline marbles form a very subordinate part of the series, which, for convenience, I call non-crystalline, to distinguish it from the older crystalline series, composed of gneisses, etc.

† Proceedings, American Philosophical Society, page 161 above.

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morphic series to the Archean, and the non-crystalline series to the Lower Silurian or Cambrian, a classification in which I but follow my esteemed friend and teacher, the lamented Prof. Hartt.

Going west from Curityba, at a distance of about thirty miles, an abrupt escarpment, called the Serrinha, or Little Serra, is met with, rising to an elevation of 1040 metres, or about 200 metres above the plateau of Curityba, which it completely dominates. This escarpment extends across the province in a general north-south direction, being, however, somewhat irregular and zig-zag towards the north, where it becomes, in a measure, confounded with the higher lands of the Assunguy region, which surpass it in elevation. In consequence of this it does not separate so completely as in the south the various systems of drainage.

This escarpment is composed, in the lower part, of the inclined metamorphic beds above described, capped by massive horizontal beds of coarse, friable, white sandstone, which rise everywhere to the same level, but vary in thickness from 20 to 100 metres, owing to the irregularities of the surface upon which they were deposited.

The Serrinha forms the eastern margin of the second region, the far famed Campos Geraes. This is a vast grassy plain, extending westward about 100 miles, with a gentle inclination towards the west, where the elevation of the highest portions becomes reduced to from 850 to 900 metres. The surface along the margin is almost perfectly level, but the innumerable streams, fed by thousands of springs and by torrential rains, soon cut themselves deep valleys, descending in the western portion of the region to an elevation of 600 metres, rendering the surface more and more undulating, as one enters the Campos. In a broad zone in the western part, there are, in addition to the irregularities due to denudation, others of greater consequence, caused by numerous immense dykes of diorite.

The character of the rock changes also in going westward, the sandstone becoming finer and tending to give way to beds of shale, which occur interstratified with the sandstone, in such a manner as to show that they belong to the same formation. In general it may be said that, in the west, as a rule, the lower portion of the formation is composed of shales and shaly sandstones, the shales in the extreme west becoming charged with silicious and calcareous concretions, and containing a few subordinate beds of a peculiar, silicious, oölitic limestone. This shaly portion is wholly, or in part, overlaid by soft sandstone, which to the eastward is the predominant formation. The sandstone appears to cover the shales over the entire region, but on this point I cannot form a positive opinion, before making a detailed study of the fossils collected, as it is possible that, in the wooded limestone region, I may have been deceived in regard to the identity of the sandstone that occurs there, with that of the open campos, further east. The rock is everywhere charged with pebbles, and often, in limited regions, changes to a pudding stone or conglomerate. In a ravine near Ponta Grossa, I found such a conglomerate, containing boulders a foot and a half in diameter, of metamorphic rocks, such as gneiss, syenite, quartzite,

etc. The most interesting is a boulder of metamorphosed conglomerate, containing rounded pebbles, the size of one's fist, of the rocks above-mentioned, united by a metamorphosed, silicious cement. These boulders undoubtedly indicate the neighborhood of some high point of the original surface of the underlying metamorphic rocks, which, before being buried, formed an island in the sea, in which the deposits of shale and sandstone were being laid down.

In the portions of this region where the sandstone is the prevailing surface rock, the soil is poor and sandy, supporting only grasses and, on the slopes, small patches of forest, in which the Arancarian pine occurs in great abundance. This tree is also extremely abundant on the metamorphic plateau of Curitiba. The shaly portions of the region have a somewhat better soil, but are still poor, in the eastern and central parts. Going westward, the soil improves, the beautiful open campos giving place to others with scattered pines and an abundance of shrubs, and these in turn, in the extreme west, where the shale is more varied in character, and where diorite and calcareous rocks are abundant, are replaced by luxuriant forests, showing the superior quality of the soil.

The geological age of this sandstone and shale has never been satisfactorily determined. The first light on the subject was thrown by a few fragmentary fossils, discovered by Mr. Luther Wagoner, Assistant of the Geological Commission, in 1876, and determined by Mr. Rathbun and myself to be Palæozoic, and probably Devonian. A few months ago, I found in the province of São Paulo, in a cherty limestone, identical with that above mentioned, a few obscure Lamellibranchs, belonging to Devonian or Carboniferous types. In my last excursion I visited the localities discovered by Mr. Wagoner, and had the good fortune to find more perfect specimens. From a bed of shale, intercalated in the sandstone, at Ponta Grossa, close by the conglomerate locality above mentioned, I found a species of Ophiuran, a few badly preserved Lamellibranchs, and species of *Lingula*, *Discina*, *Spirifera*, *Rhynchonella*, *Streptorhynchus* and *Vitulina*, strongly resembling, and probably identical with, those of the Devonian of the Amazonas. The *Spirifera*, *Streptorhynchus* and *Vitulina* are particularly well-marked Devonian types, the former being probably identical with *S. duodenaria*. In the cherty limestone at Ivahy, I found a number of species of Lamellibranchs, some of which are identical with those of São Paulo, but I could not, in the field, give them the study required to determine with certainty whether they belong to the Devonian or Carboniferous. Fragments of *Lepidodendron* also occur in the same rocks.

As above remarked, the elevation of this second region diminishes somewhat towards the west, where the heights, including the diorite ridges, rise to 850 or 900 metres, although, owing to the excessive deepening and widening of the numerous valleys, the general level is somewhat lower. From this level rises a second escarpment, known as the Serra de Esperança, to a height of 1040 metres. On the steep slope there is seen, in ascending, a considerable thickness of soft, red sandstone, overlying the shales

and sandstone of the second region, and above this a bed, 100 metres or more in thickness, of amygdaloidal and porphyritic trap, apparently a kind of trachyte. The amygdaloid is full of beautiful agates. This second escarpment is the beginning of the third geological region, the topographical features of which are very similar to those of the second or Campos Geraes region,—that is, produced by denudation on horizontal beds. The escarpment extends entirely across the province, in a north-south direction, and into the province of São Paulo, where I have recognized the same rock, in the margin of the plateau, west of the Piracicaba river. South of the river Iguassú, I am informed by Mr. Luis Cleve, a very competent observer, that it bends eastward, under the name of Serra de Espigão, and extends as far as the Serra do Mar. Prof. Hartt had already observed that the Serra do Mar, in Santa Catharina, is capped by porphyritic trap. It is probable, therefore, that these rocks cover the greater part of the interior of that province, as well as the neighboring portion of Rio Grande do Sul, in which agatiferous trap is common. A portion of the Republic of Uruguay probably belongs to the same formation. To the west the country is unexplored, but from the scanty information I could obtain, it seems probable that the trap formation extends to the river Paraná.

The surface of this region is, in general, a heavily wooded plain, but has several extensive campos, the most important ones being those of Guarapuava, which unite, to the south, with the extensive campos of Rio Grande do Sul. There appears to be a slight inclination towards the Paraná, and the river valleys being deep, present high steep slopes, that have been dignified by geographers, as well as the common people, as mountains. In point of fact, no true mountains exist in the province, outside of the metamorphic area.

No very definite data exists for determining the geological age of this enormous outflow of trap. It is certainly later than the Devonian, and is most probably Mesozoic. In lithological characters both the trap and the red sandstone, which appears to be associated with it, and to be distinct from the underlying Devonian series, resemble in a striking manner the Triassic rocks of eastern North America.

The drainage of the province is determined by the above described topographical features, and is principally toward the Paraná, only one large river, the Ribeira, flowing directly to the Atlantic. This river rises north of Curitiba, in the mountainous Assunguy region, and flows northward, into the province of São Paulo, breaking through the Serra do Mar, above the city of Iguape. Some of its tributaries flow down the slope of the Serrinha, and have cut ravines, indenting the margin of the sandstone region, but can hardly be said to drain any part of the Campos Geraes. In the same metamorphic region, between the Serra do Mar and the Serrinha, rises the principal river of the province, the Iguassú, which flows first southward and then westward, traversing the second and third regions, to empty into the Paraná. Passing over several almost unknown rivers, belonging exclusively to the third region, we come to the Ivahy,

which rises in the wooded western portion of the second region, flows for some distance northward, skirting the base of the Serra de Esperança, and finally turns westward, entering the third region, and traversing it to the Paraná. In the north, forming a part of the northern boundary of the province, is the large river Paranapanema, which, like the Igaassú, rises in the metamorphic region and traverses the two others, receiving from the province the Itararí, Rio de Cinzas and Tibagy. The latter is, *par excellence*, the river of the Campos Geraes, in which it rises and flows, to within a short distance of its mouth, where it enters the third region. It receives from the north the Pitanguí and Yapo, both of which rise in the metamorphic region, about Castro, and enter the sandstone region by deep cañons.

The diamantiferous region is principally in the valley of the Tibagy. Its tributaries, the Yapo and Pitanguí, also contain the gems, but are supposed to be less rich than the main river, perhaps because of insufficient examination. Fine diamonds are also said to have been found in the Rio de Cinzas. As far as I was able to learn, they have never been found in the Iguassú or Ivahy, although I see no reason why they should not occur, at least in the former river.

The gems occur in the sands of the river, in the numerous pot-holes, and also in gravel banks, known as dry washings, situated in the campos, at a greater or less elevation above the river. Near the village of Tibagy, are two of these dry washings. One is in a depression of the Devonian shale, in the valley of a small stream, and is only a few metres above the level of the river. It may therefore be supposed to have been deposited by the river, or by the stream that now cuts through the deposit. The section presents below a very irregular deposit of pebbles and sand, a few centimetres in thickness, which is the part washed. Above this are three or four metres of coarse, variegated sand, with pebbles scattered irregularly through the bed, which shows very irregular lines of deposition, as if deposited in an eddy. Portions of this bed have been cemented by oxide of iron, forming curious, corrugated sheets, globes, and irregular masses, of extravagant form. On top is about a metre and a half of dark-red, structureless clay. The other washing is on a hill side, near the top, at an elevation of about twenty metres above the bed of a small stream, which flows along the base of the hill, and empties into the river, at an elevation of about 100 metres below the mine. The deposit has evidently been laid down under water, but it can scarcely be attributed to any of the present streams. It also rests on Devonian shale, fragments of which are scattered abundantly through it, and consists of a bed, about three metres thick, of sand and pebbles, in which diamonds are irregularly distributed. Above this are about six metres of structureless, red clay, like that of the first washing.

The pebbles in both these washings are well rounded, and consist mainly of quartz and of quartzose rocks, with pebbles of gneiss, and of various other metamorphic and igneous rocks. The red clay continues nearly to the top of the hill, which is a long ridge, with moderate slopes, and extends for a

considerable distance horizontally, but whether it is everywhere underlaid by the diamantiferous gravel or not, I cannot state. Other washings have been opened, some twelve or fifteen miles below Tibagy, and it is probable that there are many other localities in which diamonds may be found.

As I saw no work in progress, I could form no idea of the richness of these mines. The diamonds are said to be rare, and small and poor, in comparison with those found in the river. The workings have been conducted on a very small scale and very carelessly, so that, although the mines are certainly not extremely rich, it is impossible to affirm that they would not repay better, and more systematic management. A small quantity of gold also occurs in these washings, and this metal is quite generally distributed throughout the region.

In the river, the best stones are found in the deposits in the pot-holes, which contain gravel, firmly cemented by ferruginous matter. Rarely pot-holes are found with a very hard, bluish cement, and these are reported to contain the most diamonds, which are of the best quality both as regards size and perfection. Not having seen this cement, I can form no idea of its character. The miners note as a curious fact, that in a group of pot-holes close together, one may have the bluish cement, while all the rest have the ferruginous, the pebbles of the one being quite different from those of the others.

Many of the stones shown me were broken and worn, but a fair proportion were perfect crystals. The largest ones I saw were about the size of a small grain of corn, but were irregular and broken. The most valuable stone found here, of which I could obtain an authentic account, was sold for a conto of reis (\$500). The stones are in general of good color and brilliancy.

Coming now to the question of the origin of the diamonds, it seems to me to be very evident that they are washed out of the Devonian sandstone. As already remarked, the Tibagy is almost exclusively a river of the Devonian plain. The lower portion, in the trap region, is not known to be diamantiferous, and if it is, since the stones occur throughout the whole course of the river, before it enters the trap formation, the latter may be eliminated from the problem. There remain then the Devonian rocks and the diorite. Having passed around the head of the river, and crossed it at three different places, I have become satisfied that these are the only rocks that come to the surface, to the eastward of Tibagy, that is to say, in the diamantiferous region. It is of course possible that the river may have cut down, in certain places, to the underlying metamorphic rocks, but of this there is no evidence, and it is not probable that any considerable area of such rocks are exposed, or if so exposed that it could have furnished diamonds to so wide-spread a region. Two considerable tributaries, the Yapo and the Pitangui, flow from the metamorphic region, and might be supposed to have brought the diamonds from the rocks cut through in that region, but I was unable to obtain any notice of diamonds, found in those rivers, before entering the sandstone district, and the Tibagy is diamantiferous above, as well as below, its confluence with them.

The diorite can scarcely be supposed to have furnished the gems, not alone on account of the nature of the rock, but because in the upper part of the valley, where diamonds are not uncommon, diorite is extremely rare, if it occurs at all, and because the pebbles which always accompany the gems, certainly do not come from the diorite. This last has most probably furnished, by decomposition, the red clay, above the gravel at Tibagy. The only other rocks which, as far as I observed, could have given such a clay, are those about Castro; but it would be difficult to account for its transportation from there to Tibagy, while large dykes of diorite are common near the latter place.

The secondary origin of the gravel is not far to seek. The sandstone is everywhere full of pebbles, and on every slope where this rock is exposed the surface is strewn with gravel, set free by disintegration. The primary origin of the pebbles is equally clear; they, in common with all the material of the Devonian beds, are derived from the metamorphic series. That the diamonds have the same primary origin can hardly be doubted, as they cannot be supposed to have been produced in the sandstone, which does not show the slightest sign of metamorphism or of crystallization of any kind. That the diamond must have originated in some series rich in crystals is evident from the fact, that it is always accompanied by a variety of crystals, called by the miners *informations*. I have not had an opportunity of determining those of Tibagy, which do not differ materially from those already described from Bahia and Minas Geraes.

It may then be regarded as extremely probable, if not absolutely certain, that the diamonds originated in the metamorphic series; that, during the Devonian age, they were washed out and redeposited in the sandstone, from which they have been again extracted, to find their third resting place in the sand banks and pot-holes of the river, and in the gravel deposits of the campos. May we not suppose that the rare patches of gravel, with blue cement, are nests formed in the sandstone and laid bare by the formation of pot-holes?

As to what portion of the extensive metamorphic series constituted the original matrix of the diamond, I could obtain no data in Paraná. The evidence on the subject, which is being slowly accumulated, tends apparently to the confirmation of the old idea, that it belongs to some part of the itacolumite series.

After my studies in Paraná, it seems to me probable that the extensive high sandstone plateaus of Central Brazil, which we have been accustomed to consider of Tertiary age, are in reality much older, and probably Palaeozoic. It is yet too early to form a decided opinion respecting them, but if my suspicion regarding their age proves correct, we can explain the course of geological events in Brazil much more satisfactorily than at present.

The lower plateaus, of almost precisely similar topographical and lithological character, along the coast and on the Amazonas, are certainly later than the Cretaceous; but none of those, whose age can be positively determined, rise much above 1000 metres, and the higher plateaus of the interior have been referred to the Tertiary, solely on resemblances in lithological characters which, in Brazil, are peculiarly deceptive and untrustworthy.